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Low-cost Optical Readers with High Performance

J. R. Parks, National Physical Laboratory, and P. O. Styan, Plessey Instrumentation

As the computer age develops, data processing speeds continually increase and methods of data capture are sought which minimise delays in the processing cycle. Optical data capture—the reading by machine of printed or written marks or characters—falls into three main classes: optical mark reading (OMR), optical character recognition (OCR) and hand-written character recognition (HCR). These methods of data entry have, surprisingly, made rather a slow penetration in their respective markets. OMR, after being available for 35 years, is now well established and profitable for supplier and user alike. OCR, after 15 years, is just entering its heyday and competing with OMR, while HCR, after five years, is still largely a novelty but with enormous potential for the future. Among OCR equipments available commercially there are machines of very high performance from Plessey which incorporate the benefits of research into recognition techniques carried out at the National Physical Laboratory.

The Series 4200 OCR readers announced by Plessey in October 1970 owe their basic philosophy and some of their techniques to work carried out in the Automatics Division (now Division of Computer Science) of NPL between 1962 and 1966. This work led to the demonstration of a machine—'Cyclops'—capable of reading stationary numeric characters of the poor print quality typical of many high speed printing machines.

In mid-1960s Plessey entered the OCR field and the Plessey research laboratories at Poole began development of an OCR reader, based on the NPL concept of feature detection using analogue signals. This work was part-sponsored by the Ministry of Technology (now incorporated into the Department of Trade and Industry) Advanced Computer Techniques Project programme. Following the demonstrations of experimental prototype machines—'Oscar' and 'Ochre'—by Plessey, it was realised that the new reading techniques evolved would have considerable commercial potential. Consequently, the design of a pre-production machine was undertaken by a product division at Poole culminating in the present 4200 series of readers, launched in October 1970.

OCR philosophy

Based upon early studies at NPL, it was decided that the largest potential market for OCR lay in relatively low-cost systems limited to a specific character style but with the greatest possible tolerance of printing defects. This led to a combined NPL/Plessey philosophy based on analogue feature analysis, a technique ideally suited to the recognition of degraded print. By comparison with letterpress and litho printing, low quality print is produced in large quantities by high speed computer printers on documents used for billing

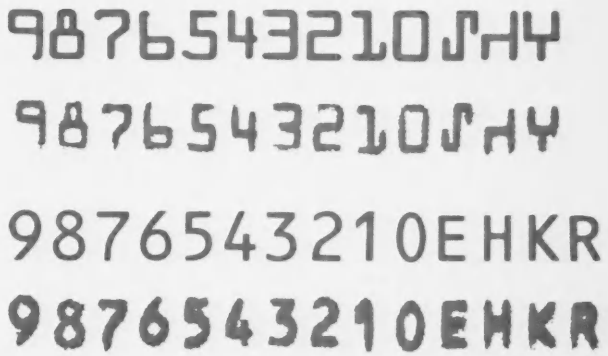


Figure 1. Two examples of degraded print quality together with the perfect characters for comparison.

operations, particularly by public utilities, insurance companies, etc. These 'turn-around' documents are returned to the producing authority where the computer file is updated via an optical reading system.

Several factors detrimental to OCR reading can be attributed to line-printers. The ribbons vary in quality and wear rapidly. With a new ribbon considerable ink splashing can occur causing spots to surround the character limbs. Conversely, towards the end of useful ribbon life, voids form in the limbs and generally the characters appear a lighter shade of grey. Hammer pressure variations and maladjustments cause uneven character impressions to occur which give rise to excessive thickening of, say, the lower limbs and virtual absence of others. As well as wide differences in print quality, the turn-around document is subject to creasing and deterioration due to handling by third parties. Some of these defects are shown in Figure 1.

An OCR manufacturer, having very limited control over print quality, must offer a reading technique which is reasonably tolerant of these degradations. Although print specifications for the OCRA and OCRB ('A' and 'B' fonts) have been defined in terms of print contrast, permissible spots and voids, etc, they serve mainly as a guide to character shape and size for the OCR design engineer.

A major aim of the Plessey OCR philosophy has been to design readers as standard computer peripherals offering high reliability and freedom from maintenance. To this end, widespread use has been made of both analogue and digital integrated circuits. This is exemplified by the monolithic array of silicon photodiodes in the reading head or camera. In association with the Allen Clark Research Centre, Caswell, the development of a large-scale integrated array of photoelements

Table 1. 4200B test results

Paper speed:	221 in./sec.	Total number of documents per pass =	148,200
Document throughput:	1200/min.	Total number of characters per pass =	4,058,400

	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5
Document reject rate	0.029%	0.035%	0.024%	0.034%	0.029%
Character reject rate	1.06×10^{-5}	1.28×10^{-5}	1.06×10^{-5}	1.43×10^{-5}	1.06×10^{-5}
Substitution rate	Nil	Nil	Nil	Nil	Nil

(photodiodes plus *most* switches) with integral scanning circuitry had been running concurrently with the evolution of recognition techniques since 1967. Apart from assuring reliability in one of the world's first solid state reading heads, the photodiode array extracts data from a complete character field in a single vertical scan and affords a maximum reading rate of 3,000 characters/sec.

The method used recognizes individual characters from the combination of geometric features which they possess. Any single feature, such as a 'hooked top', is common to several characters—2, 3 and possibly 7—but taken in combination with other features, individual characters can be identified uniquely. By careful selection of the set of features it is possible to identify characters correctly when some of the features are missing, due to poor printing impression or some other factor. This is a significant improvement over many other systems which cannot exploit character structure directly and are therefore limited in their ability to make a 'best guess' from the information available. Although some features may be missing and characters still correctly recognised, the method of extracting features must be as reliable as economically feasible. In order to avoid problems inherent in deciding for each isolated point in the character image, whether it was intended to be black or white, an analogue system of feature detection was devised.

The machine demonstrated at NPL detected the presence of relatively complex features. A modified system studied during the collaboration period with Plessey demonstrated that performance improved if the relative positions of the features could also be determined: this information was implicit, but discarded in the earlier machine. The later system demonstrated, by computer simulation, the recognition of a full alphanumeric set of very low quality with simple features.

The 4200 readers

The essential elements of the Series 4200 readers—the OCR camera and the recognition electronics—are shown in the accompanying OCR system block diagram (Figure 2). Documents are transported past the reading station via a rotating drum on to which they are held by either vacuum or a belt. A single line of printed OCR characters is observed by the camera lens which focuses character images on to the surface of the integrated photodiode array. An area of the document equal to three vertical character fields is illuminated by a symmetrical pair of fibre optic light guides.

The processes of recognition indicated in Figure 2 are similar in principle for both the 4200A and B. The pre-processing stage essentially converts the raw video into waveforms which are suitable for subsequent analysis. Character features or rudimentary character patterns are then detected from the processed video.

For OCRB recognition, spatial features are detected. These are groups of nominal black and white points geometrically related to the characters and covering the complete character field. OCRA recognition, however, is based on simpler features designed to detect horizontal and vertical lines, although there are similarities in the analogue processing circuits for both fonts.

The use of a solid-state camera combining high speed with multi-line (or retina) scanning and analogue feature detection are the main common characteristics of the 4200 readers. If the feature patterns satisfy a series of logic tests then character data is output from the reader. As part of an on-line system, the OCR data now enters a host computer whose software would perform data vetting and editing. Alternatively, in an off-line mode, data handling is the function of an OCR processor which also controls the recording and formatting of data on to a storage medium, usually magnetic tape.

Reading tests

Recently, 4200A and B machines have been subjected to stringent reading tests by potential users. The results are presented in Tables 1 and 2 and are indicative of the high performance available from those readers.

The 4200B reading test formed part of a complete off-line system test, with document feed and sorting being controlled by a dedicated data processor which was also responsible for data verification, buffer storage and formatting prior to recording on magnetic tape. In addition to a single line of OCRB numerics, the test documents bore a line of pre-printed OMR boxes, so facilitating manual data entry. In fact, the vertical and horizontal stroke detecting techniques normally used in the 4200A reader to detect OCRA numerics were conveniently applied to detect hand-made marks. In this

Table 2. 4200A test results

Paper speed:	100 in./sec.
Document throughput:	400/min.
Total number of documents:	165,364
Total number of characters:	8,102,836
Document reject rate:	0.35%
Character reject rate:	7.2×10^{-5}
Substitution rate:	0.62×10^{-6}

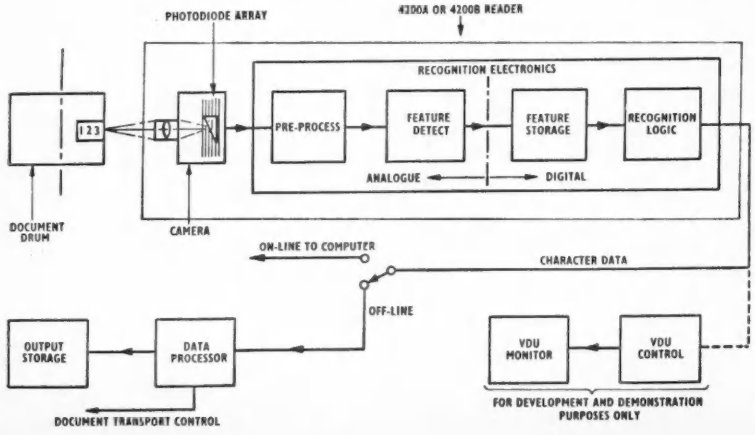


Figure 2. Block diagram of the OCR system.

application, a separate clock track was not in demand, the leading (vertical) edges of the pre-printed boxes being used for the purpose of gating horizontal data marks.

The 4200B test documents were printed by a computer printer, of the drum type, at 1200 lines/min. Two equal sets were passed, each representing a different ribbon type used from mint condition until approximately 27.5 million character impressions had been made, each document bearing several lines of blanket printing. The ribbon materials were silk and nylon, costs per ribbon being £22 and £4 respectively. Since, in the live system, the ribbons on each of 10 printers were to be changed daily, a considerable saving in operating costs would be possible if the cheaper, nylon ribbon could be used. As shown in Table 1, similar overall reject rates were obtained for each of five separate passes of all the documents; reading performance was insensitive to ribbon life and type.

The 4200A reading test was in some respects more severe than that for the 4200B since several different types of line printer (including chain types), encoder and ribbon were used in preparing the test documents. Also, relatively little control was exercised to ensure freedom from printer maladjustment, interfering marks on the OCR code-line, etc.

The target performance for the test was specified as 3 per cent document reject rate after three passes, i.e., three reading attempts, and substitution (or undetected error) rate better than one character per million characters read. The test results are given in Table 2 and formed a key factor in the placing of an order for a substantial number of 4200A readers by Nixdorf Computer AG. This customer sees a major market opportunity in the German banking business which will require considerable numbers of optical character readers. Delivery of the first machines began in early 1973 and will continue over the next five years.

An off-line OCR system, based on the 4200B reader, will shortly be delivered to the Department of Environment for processing driver and vehicle licence renewals at the newly-established computer centre in Swansea. Some public utilities are replacing existing OCR equipment with 4200 readers.

It is generally estimated that the greatest impact on the potential OCR market will be made by low-cost document reading systems in which Plessey is operating initially with the Series 4200 readers. Other low-cost document reading systems are in course of development. NPL has now completed a design for recognition of hand-written characters.

More information: Mr. P. O. Styan, Plessey Instrumentation, Sopers Lane, Poole, Dorset, or Dr. J. R. Parks, Division of Computer Science, National Physical Laboratory, Teddington, Middx TW11 0LW. Tel: 01-977 3222, ext. 3097.

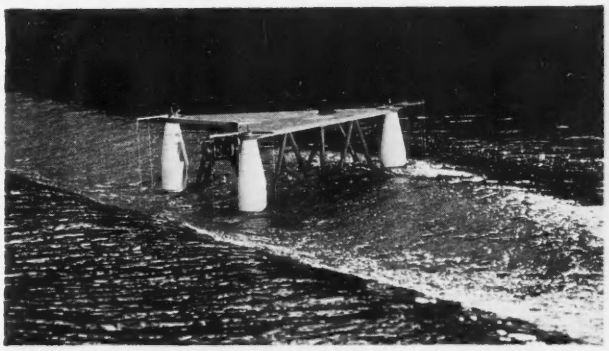
Aiding Britain's Offshore Programme

Growing exploitation of the natural resources which lie off Britain's shores has brought in its wake increasing calls on the marine investigatory facilities and expertise at the National Physical Laboratory, Teddington. Over the past few years, the NPL has carried out several design evaluation and operational studies for the offshore oil industry. This work was attracted principally by the Laboratory's expertise in hydro- and aerodynamics but other disciplines are now playing an important role. The Ship Division, the Division of Maritime Science and the divisions of the Materials Group are all concerned in this field.

The Ship Division has versatile facilities suitable for carrying out model experiments on all manner of ships and marine structures in realistically simulated environmental conditions.

Many commercial investigations have been carried out on a cost-repayment basis for some of the largest offshore operators. This work has been concerned with the performance of semi-submersible drilling barges and their mooring systems, the stability of pipe-laying barges, the towing to site of underwater oil storage units and the efficiency of floating breakwaters. One investigation was carried out on a model of a semi-submersible drilling barge. The model was moored by nine dynamically scaled cables in the 30.5 metre square seakeeping basin at Feltham and measurements were made of its six components of motion and the cable tensions in a wide range of possible sea conditions, wave directions and wind loadings. The results were used to determine whether the drilling barge and mooring arrangement were suitable for winter working in the northern North Sea, an environment considerably more hostile than that for which the barge was originally designed.

Such work to determine whether existing structures could be used safely and economically off the British coast was typical in the past. The current trend, however, is towards new designs of structures and control systems for dealing with future industrial requirements. Working in progressively deeper water, for example, poses many new problems for oil exploration, production and transport. Dynamically positioned drilling ships and barges—kept on location by means of auxiliary thrust devices instead of by mooring—are likely to come into their own for exploration, new designs of production platforms are envisaged, on-site oil storage will probably become more attractive and new methods of transporting oil to shore will be required. All these problems are currently being investigated by the division, both on commercial contract and as part of the internal research programme.



Model of a semi-submersible drilling barge in the 30.5m. square seakeeping basin at Feltham being subject to irregular waves typical of the North Sea.

The Division of Maritime Science possesses comprehensive laboratory facilities, some unique in the United Kingdom, for investigating fluid flows and their interaction with structures of all kinds, including offshore structures. The division also operates a Marine Trials Base at Hythe on Southampton Water which is extensively equipped and staffed to carry out seagoing investigations into the performance of marine craft and structures and to record the relevant environmental data.

Wind-tunnel tests at Teddington are made on models of specific projects, as for example, bridges, ships and tubular lattice structures typical of drilling rigs, to measure forces and pressure distributions and to investigate the oscillatory response of structures to fluid flow. Such work, carried out over a number of years, has created an unrivalled pool of expertise which is directly applicable to the offshore industry.

At the Marine Trials Base a wide range of purpose-built equipment has been developed to meet stringent requirements of accuracy, robustness and adaptability for the acquisition of

data at sea. The base has been involved in a number of investigations directly relevant to the offshore industry, such as on floating breakwaters and wave dumping devices. Assistance has been rendered to a major oil company in sea-state measurements. Consideration is currently being given to investigations on large-scale and full-scale structures at sea in support of DTI research requirements. The facilities at the base coupled with the wide sea-going experience of the staff place it in an exceptionally favourable position to carry out such work.

In August 1972 the NPL was invited to act as a national focus for research into loads on offshore structures due to fluid forces—waves, currents and winds. To assist in this task, the NPL set up an informal advisory group composed of members directly involved in work on offshore structures and with particular knowledge of the problems of environmental loading. The advisory group has held several meetings and has made considerable progress towards its objectives of assessing research requirements and formulating a research programme, the results of which would benefit both designers in industry and government departments concerned with safety aspects of offshore structures.

The Materials Group has a growing interest in the behaviour of materials which have or might have offshore applications. The Corrosion Advisory Service has been in existence for a number of years and is backed by experienced staff and extensive experimental facilities which may be used when a problem cannot be solved with existing information. As an example of the latter situation, it has been found that there is a lack of knowledge on the fatigue of metals and alloys induced by corrosion in sea water. A programme of work is shortly to be initiated in this field which is clearly of relevance to the stability and safety of offshore installations.

Also of relevance is a programme to study the low temperature properties of materials which might be used for the transport and storage of liquid natural gas. In this work NPL has been concerned mainly with aspects of safety within the industry. A possible spin-off might be the replacement of the expensive alloys now used by a relatively cheap steel with suitable cryogenic properties.

Fibre-reinforced cement is a material finding increasing application in offshore structures and the Materials Group is interested in methods for the assessment of this material including factors which affect its reproducibility.

It is expected that the involvement of the Laboratory with aspects of the offshore industry will continue and increase over the next few years. In this way a contribution will be made to improving the competitive position of British industry in this field in addition to enhancing safety and reducing the risk of marine pollution.

More information: National Physical Laboratory, Teddington, Middx. Tel: 01-977 3222.

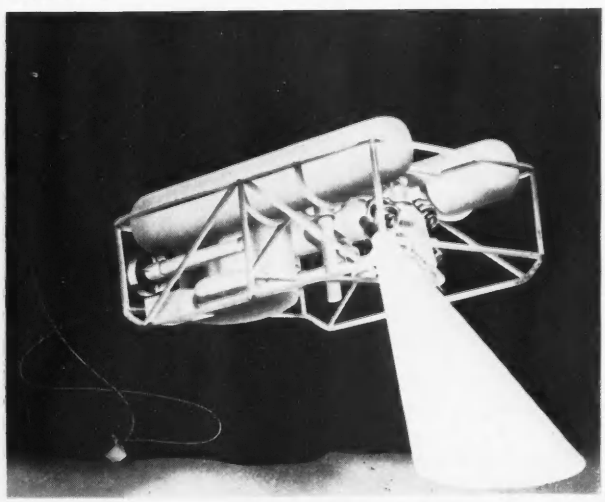
Robot Vehicle for Sea-bed Exploration

An unmanned cable-controlled submersible vehicle for sea-bed exploration is being built by British Aircraft Corporation, Electronic and Space Systems Division, for the Institute of Geological Sciences. The submersible is being designed and built at Bristol under an eight-month £36,000 contract awarded by the Research Division of the Department of Trade and Industry.

Although intended primarily for use in a survey of the United Kingdom's continental shelf and for obtaining rock core samples from the sea-bed, allowance is being made for the possibility of other countries becoming interested in the vehicle.

Approximately the size of a mini-car and weighing about 10 cwt., the electrically-controlled submersible will be able to skim or "fly" over the sea-bed to carry out a preliminary survey. Control will be from a surface vessel. On board the submersible television and stereo cameras will film and record interesting rock areas. On the selection of an area, the vehicle will land on the sea bed so that its rock drill can take a 1-cm diameter core sample.

An artist's impression of the manned submersible vehicle being built for the Institute of Geological Sciences by the British Aircraft Corporation.



The submersible can operate at depths of up to 2,000 ft. A weight or sinker connected by cable from the surface support ship rests on the sea-bed. From this sinker a cable extends to the submersible, which has an operating radius of 150 ft from the sinker. This arrangement helps to stabilise the craft; also, by not having a direct moving connection from the ship to the vehicle, cable drag is reduced. While the submersible is in service it is expected that associated investigations will take place into determining hydrodynamic resistance of cables.

Adaptable

The vehicle, adaptable for different applications, is the result of a comprehensive system study by the British Aircraft Corporation. To meet the requirements of the Institute of Geological Sciences, the payload consists of a pan and tilt head on which are mounted both cameras and rock drill, built into a simple space frame structure. Three remotely-controlled electrical thrusters will control the submersible's horizontal movement and its 'flying' height. Retrieval of the submersible from the sea bottom by the surface support ship is by the umbilical cables. All the control equipment is contained in a systems control console on the support ship: no special on-board facilities will be needed.

It is expected that the submersible vehicle will enter service early next year, prior to which she will undergo initial sea trials at Portland, Dorset. The contract price of £36,000, which is being funded jointly by DTI and the Natural Environment Research Council, does not include the camera equipment.

More information: Mr T. C. Bickerton, Publicity Officer, Bristol, British Aircraft Corporation Ltd., Electronic and Space Systems, Filton House, Bristol (tel: 0272 693831, ext. 935); Mr J. H. Rendall, Department of Trade and Industry, Research and Development Requirements Board/3, Abell House, John Islip Street, London SW1P 4LN (tel: 01-834-4422, ext. 139).

Finding Wrecks by Sonar

Another underwater exercise in which both the Department of Trade and Industry and the Natural Environment Research Council are involved has just been completed in Torbay. It consisted of four weeks of trials to improve existing techniques for the detection by Sonar of aircraft wreckage in the sea. The techniques used, however, could also have applications in a number of other situations, such as the location of ship wreckage, the tracking of oil pipe systems and the assessment of inshore sediment accumulation. It was therefore understandable that many organisations should have taken an active interest in the trials, which were organised through the central coordination of DTI's Marine Technology Support Unit.

The Natural Environment Research Council's Unit of Coastal Sedimentation was represented at the trials because of its responsibilities for measuring and quantifying the process of sediment accumulation and changes in coastal areas, which also affects the inshore environment. Trinity House was present in view of its work in ensuring safe navigation channels after sinkings, while the Ministry of Defence also took an interest in the trials. The British Petroleum Co Ltd. has concerned itself with the investigations because of the system's possible applications in tracking oil pipe systems used in delivering North Sea oil: this company took part in initial trials last October.

Carried out on behalf of the Chief Inspector of Accidents, DTI, the trials were designed to evaluate the limitations of Sonar detection of aircraft wreckage and to assess how technically complicated or advanced the equipment has to be to ensure that the technique is effective. During the trials, however, consideration was given to other possible applications for Sonar detection.

Sonar sweeps were made over a particular area in which wreckage had been positioned. The Sonar targets were specially chosen to explore detection problems arising from various thicknesses used in aircraft structures: these are often so thin that the structures are almost transparent to Sonar. It had been intended to use only materials simulated to represent wrecked aircraft but it was subsequently found possible to use actual aircraft wreckage and successful trials were carried out with these targets.

Structures to simulate aircraft wreckage being erected on the beach prior to being positioned on the sea bed.

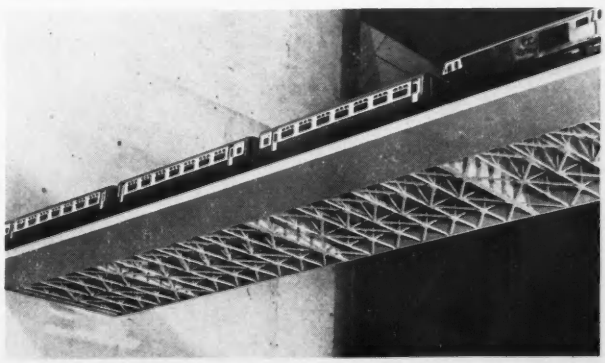
An unusual feature of the trials was the use of magnetic tape for the recording of the raw data required for subsequent numerical analysis. With the usual practice of capturing signals on a paper recorder there is a tendency for some of the detail of the raw signals to be lost. By using the more sensitive magnetic tape it was possible to make a more accurate assessment of the often small differences in signal strengths from the various types of wreckage.

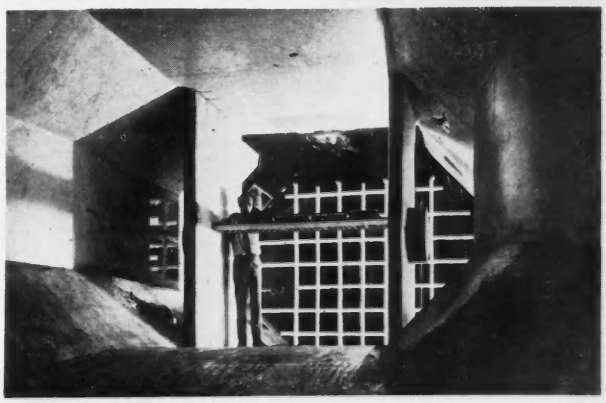
As other means of navigation did not offer a sufficiently high degree of accuracy for this type of operation, the targets themselves were used for lining up. An acoustic triangulation system operated by divers was used for this work.

More information: Mr D. W. Colvin, Marine Technology Support Unit, DTI, Building 7, Atomic Energy Research Establishment, Harwell, Didcot, Berks. Tel: Abingdon 4141, ext. 2689.

Wind tunnel tests on bridges

One of the most comprehensive wind tunnel investigations ever undertaken into the aerodynamics of a bridge has been completed at the National Physical Laboratory, Teddington. The tests were in preparation for the building of two identical bridges, 30 km. apart, to carry road and rail traffic over the River Parana in the Argentine. The Zarate-Brazo Largo bridges, with main spans of 330 m., will be the longest cable-stay bridges in the world. At NPL the tests were carried out by staff of Atkins Research and Development, part of the W. S. Atkins Group. This firm has been acting as consulting engineers on aerodynamics and certain other aspects of the bridges. Road and rail traffic will run alongside each other, but the side of the bridge carrying the railway, which will be adjacent to the edge of the box-girder deck, will require cables of twice the stiffness of those on the other side of the structure. The complexities of the design made it necessary to study in detail the possibility of wind-induced oscillations of each bridge. Tests were carried out both with a wooden model representing a bridge under construction and a model bridge in the completed state. The largest wind tunnel at Teddington was used during the investigations. There are several low-speed wind tunnels at NPL with working sections ranging from 0.9 m. × 0.9 m. to 4 m. × 2.7 m. These tunnels are employed for investigating effects of wind on ships, buildings and structures of all kinds.





Getting Organic Coatings to Stick to Anodised Aluminium

by P. Walker, Atomic Weapons Research Establishment, Aldermaston

In an earlier issue of *New Technology* (No 58, May 1972) Peter Walker discussed some aspects of the adhesion of organic surface coatings to metals, in rather broad terms, without going into too much detail about specific metals. He described the effects of surface preparation and showed that major improvements in adhesion could be obtained by correct and efficient surface preparation. Here he discusses the surface preparation of aluminium and some aluminium alloys, paying special attention to the effects of the anodising process. He describes some particularly interesting work carried out at Aldermaston on behalf of the Ministry of Defence on the chromic acid anodising process. This is the fifth in a series of articles on various aspects of AWRE's work in the field of organic protective coatings.

Aluminium has in the past been considered to be a difficult metal to paint, in that the adhesion of applied coatings is initially low, and deteriorates with ageing. I am sure that many readers are familiar with this problem, particularly if they own an aluminium caravan, on a marine site. The paint flakes away at sharp edges, and cracks and peels, where the panels flex. Production aluminium and aluminium alloys are smooth, bright, and heavily contaminated with non-drying fatty oils used as rolling lubricants in the manufacturing process. This contamination is very difficult to remove by non-chemical means, and certainly the solvent degreasing commonly practised is insufficient to remove much of the contaminant.

A variety of techniques may be used to promote good paint adhesion, including alkaline pickling, chromate conversion coatings, sulphuric and chromic acid anodising, and the use of wash primers after a suitable degreasing process. In Table 1 I have attempted to show the progressive improvement in adhesion which can be obtained by carrying out progressively more efficient surface preparations or pretreatments.

The paints applied were a two-pack epoxide of the polyamide cured type, and an aliphatic isocyanate adduct cured polyurethane paint, two substrates, L16 (99 per cent aluminium half hard) and L70 (aluminium 4.4 per cent copper, 0.7 per cent magnesium, 0.7 per cent silicon, 0.6 per cent manganese), were used.

The table very clearly indicates that solvent swabbing is dangerously ineffective in removing contamination and much more sophisticated methods are necessary if the true adhesion potential of the two coatings is to be realised.

A most interesting aspect of the results is the apparent adhesion failure obtained on alloy L70 on the chromic acid anodised panels. This observation accords well with previous reports of unexplained adhesion failures of epoxide paint systems on this alloy—used in naval aircraft—which had led to a programme of work being carried out for the Ministry of Defence. This programme of work is far too large to be covered adequately here, except to describe some of the more interesting results and conclusions. Briefly, the programme called for an examination to be carried out of five paint systems applied to five alloys under three test conditions. This work was required to be repeated for 30 different anodising and post-anodising conditions—a monumental piece of work!

The five paint systems investigated were: epoxide primer and finish to DTD 5555; wash primer to DEF 1408 and epoxide finish to DTD 5555; phenolic resin modified wash primer to DTD 5555 and epoxide finish to DTD 5555; phenolic resin modified wash primer to DTD 5555 and synthetic finish (alkyd based) to DTD 827, and synthetic primer and finish to DTD 827.

Figure 1. The effects on alloy L16 after immersion in an aged bath solution with mineral oil contamination (magnification ×5,000—electron).

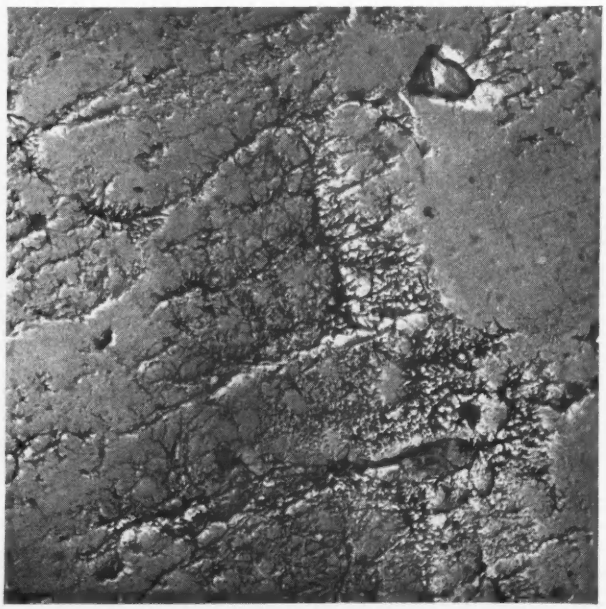
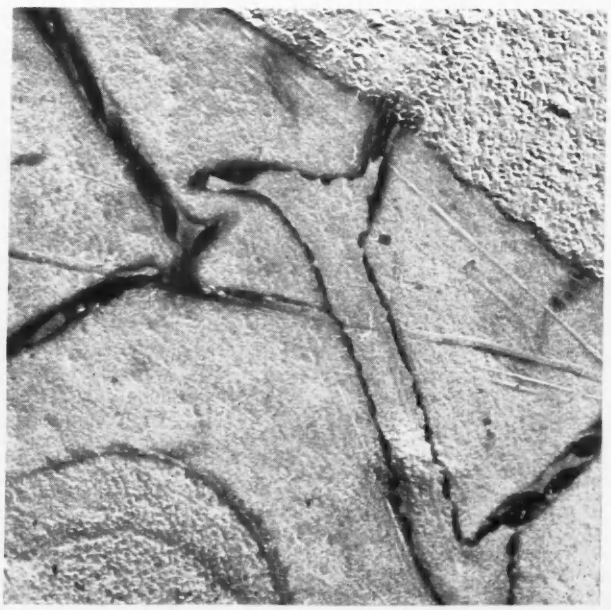


Figure 2. Alloy L70 after immersion in a bath solution with high lanolin contamination. The boundary between adjacent areas is clearly shown (magnification ×5,000—electron).



The five alloys treated were L16 and L70 (both described earlier), L72 (99.7 per cent aluminium coated on aluminium, 4.4 per cent copper, 0.7 per cent magnesium, 0.7 per cent silicon, 0.6 per cent manganese), DTD 182 (aluminium 7 per cent magnesium) and DTD 687 (aluminium 1 per cent zinc coated on aluminium, 0.9 per cent copper, 2.7 per cent magnesium, 5.8 per cent zinc).

All the adhesion measurements were carried out by the 'direct pull-off' method in which discs are stamped from the test panel and bonded between two cylindrical test pieces before being broken on a Hounsfield Tensometer.

Anodising conditions

In general, the degreasing and anodising procedures were carried out to the dictates of DTD 910C, although there were obvious deviations from this in the composition of the bath and levels of contamination where the effect of specific variables were being examined. Variables examined included the concentration of active solutes in the bath, and the incorporation of inorganic and organic contaminants at several levels. The results indicated that variations in the concentration of active solute in the anodising bath could cause considerable variation in the adhesion of the applied paint system. This variation was greatest with alloy L70, particularly when the phenolic resin modified wash primer was used.

Although the presence of inorganic contaminants such as chloride, sulphate and copper led to a far greater incidence of apparent adhesion failure, the values recorded were generally acceptably high, but here again adhesion failures associated with the phenolic resin modified wash primer were more numerous. The effect of organic contaminants such as lanolin and mineral oil was noticeable and many apparent adhesion failures of the phenolic resin modified wash primer occurred, although it is only fair to say that the levels of contamination were greater than those which could be readily expected in normal practice. Electron microscopy showed that the anodic films produced in baths containing a high level of organic contamination were generally rougher and more disturbed than those produced in a contaminant free bath. Typical films are shown in Figures 1 and 2.

Post anodising variables

A wide range of post anodising variables was examined, including type of rinsing water, presence of inorganic contaminants, sealing temperature and delay period before painting. The choice of either demineralised or town water for the rinse water had little effect on the measured adhesion, but the presence of inorganic contaminants resulted in a fair number of adhesion failures—perhaps more than any other single factor.

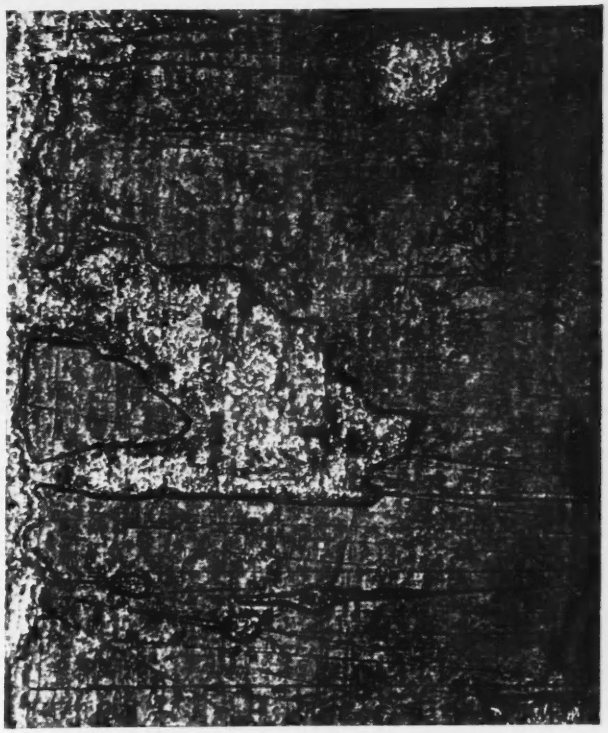


Figure 3. The anodic film on this alloy L70 was dyed blue which helped to show clearly under microscopy the cohesive failure in the anodic film (magnification ×1,000—optical).

Where sealing operations were carried out at different temperatures those panels sealed at 100°C showed the lowest adhesion. and there were fewer failures after sealing at 60°C. Delays after sealing and before painting resulted in low adhesion values which were not confined to the phenolic modified wash primer.

Consideration of the test results for the complete programme showed about 80 per cent of composite anodic film/paint system failed in cohesion of one or other of the coats of paint. Since we were examining the incidence of adhesion failure it is the remaining 20 per cent of the results which are important, and of these half occurred at values below 2,000 lbf/in.²—this is a relatively low value! Of this 10 per cent, almost 85 per

Table 1. Effect of surface preparation on the adhesion of coatings to L16 and L70

Surface preparation alloy	Two-pack epoxide		Two-pack polyurethane	
	Adhesion lbf/in²	Site of failure	Adhesion lbf/in²	Site of failure
No preparation /L16	1850	100% A/M	1900	100% A/M
No preparation /L70	1600	100% A/M	1850	100% A/M
Solvent degrease /L16	2200	60% A/M	3000	30% A/M
Solvent degrease /L70	2050	90% A/M	2550	80% A/M
Alkaline pickle /L16	4700	80% C/F	4490	80% C/F
Alkaline pickle /L70	4350	30% A/M	4150	20% C/F
Wash primer /L16	4300	80% C/Wp	4500	20% C/WP 80% C/P
Wash primer /L70	4250	100% C/Wp	4000	60% C/Wp
Chromate conversion coating /L16	5600	20% C/F	4450	60% C/P
Chromate conversion coating /L70	4500	30% C/F	4400	30% C/F
Chromic acid anodise /L16	5000+	Adhesive failure	4340	90% C/P
Chromic acid anodise /L70	4400	40% A/M	4350	90% C/F 10% A/M

A/M = adhesion failure from metal
C/P = cohesional failure of primer.
C/WP = cohesional failure of wash primer
C/F = cohesional failure of finish

cent—8.5 per cent of the total—involved the use of the phenolic resin modified wash primer. Many of these failures involved the alloy L70. These results showed that the anodic film of L70 was in some way different to that on other alloys, and that the phenolic resin modified wash primer failed to adhere to some anodic films, notably those on alloy L70.

In considering the composite metal/anodic film/paint system, it is obvious that there are many potential sites of failure, ranging from adhesion failure from the anodic film to intercoat adhesion in the paint system and cohesive failure in any coat of the system. It could be argued that of these sites of failure, adhesion from the anodic film is the most serious, since it would leave the anodic film unprotected. However, there are two other sites of failure which have not been considered: these are the adhesion of the anodic film to the metal, and a cohesive failure within the anodic film. Neither of these failures were initially considered to be at all likely. The finding that the anodic film in L70 appeared to be different, coupled with the discovery that organic contamination during the chromic acid anodising process produced rough irregular anodic films, suggested that a cohesive failure in the anodic film might be worthy of consideration.

Further electron microscopy revealed that many of the anodising treatments produced rough broken films and these were often associated with an apparent adhesion failure in the other tests. Finally, sections through the anodic film before and after painting showed that the anodic film was either penetrated by superimposed paint layers or dissolved.

Failure of the anodic film is perhaps possible where there is use of wash primers which contain phosphoric acid. In a final experiment the anodic film of L70 was dyed blue, and an adhesion test carried out. Microscopy clearly showed a cohesive failure within the anodic film! This cohesive failure is shown in Figure 3. There is therefore strong evidence for supposing that many of the failures reported as adhesion failures were in fact cohesive failures. It appears likely that some variables in both the anodising bath and in the post anodising treatment produce films which are either cohesively weaker than other films, or are more readily damaged by wash primers, leading to failure within the anodic film.

It also appeared from the work, that there were some failures on panels produced from anodising baths which were operated within the mandatory clauses of DTD 910C. Microscopic examination produced evidence of lack of reproducibility, which was further exemplified by a considerable variation in the weight of the anodic film. All the evidence tended to show that it was the overall quality of the anodic film which governed the paint adhesion, rather than any single property of the film.

It is, however, apparent that although a great deal of work has been done on the anodising process, the interactions between anodic film and paint system are still imperfectly understood, and much more work is indicated before the true potential of the dual system is fully realised.

[The author wishes to thank the Ministry of Defence for permission to publish this paper.]

More information: Mr. P. Walker, Atomic Weapons Research Establishment, Aldermaston, Reading, Berks. RG7 4PR. Tel: Tadley (07356) 4111, ext. 5012/7659.

news

Industrial Technologies chairmen named

The committee structure is now complete for the industrial technologies campaign now being undertaken by the Department of Trade and Industry to promote a greater awareness in industry of the importance of multidisciplinary technologies. As previously announced, Mr. Gilbert A. Hunt, managing director and chief executive officer of Chrysler UK Ltd., is chairman of the main Committee for Industrial Technologies, with Dr. H. Peter Jost, managing director of KS Paul Products Ltd., as deputy chairman. Dr. Jost is also serving as chairman of the subsidiary committee on tribology.

Chairmen of the other specialised committees are: terotechnology—Major General Sir Leonard Atkinson, director Weir Engineering Industries; education and training—Dr. A. H. Chilver, vice chancellor, Cranfield Institute of Technology; corrosion—Mr. J. B. Cotton, part-time consultant, Imperial Chemical Industries Ltd.; materials handling—Mr. H. Surtees, managing director, Easams Ltd.; information and publicity —Mr. N. Shepherd, chief information officer, DTI.

All the chairmen of the subsidiary committees are members of the main committee. Other members of the Committee for Industrial Technologies are: Mr. H. Darnell, director of engineering, British Steel Corporation; Mr. G. E. Darwin, managing director, mechanical engineering division, Babcock and Wilcox Ltd.; Mr. P. Fisher, head of production department, Trades Union Congress; Prof. Sir Brian Flowers, chairman, Science Research Council; Mr. M. W. Leonard, secretary, Council of Engineering Institutions; Dr. K. A. G. Miller, engineering advisor, Imperial Chemical Industries Ltd.; Mr. A. E. Singer, deputy managing director, Tesco Stores (Holdings) Ltd.; Dr. C. Whitworth, vice chancellor, University of Salford; Mr. L. S. Wigdor, deputy director general, Confederation of British Industry; Dr. B. F. Willetts, Plessey Telecommunications Ltd.; Mr. A. J. Havelock, director, industrial technologies branch, DTI; Mr. N. L. Parr, director of research, Ministry of Defence (PE); Mr. W. J. Reiners, director of research requirements, Department of the Environment; Mr. P. H. Stephenson, head of research requirements, DTI; and Dr. H. Campbell, industrial advisor, DTI.

More information: The Department of Trade and Industry, Industrial Technologies Secretariat (M4), Room 540, Abell House, John Islip Street, London SW1P 4LN. Tel: 01-834 4422, ext. 341.

Precision electromagnetic measurements conference

The 1974 Conference on Precision Electromagnetic Measurements will be held from July 1–5 at the Institution of Electrical Engineers in London. Ninth in the biennial series of conferences which began in 1958, it will be the first to take place outside the United States.

The conference is being organised by the Royal Society and the Institution of Electrical Engineers in conjunction with the Union Radio-Scientifique Internationale, the Institution of Electronic and Radio Engineers, the National Physical Laboratory and the Scientific Instruments Manufacturers' Association.

More information (including submission of papers): 1974 CPEM Secretariat, c/o Conference Department, The Institution of Electrical Engineers, Savoy Place, London WC2R 0BL.

Hydrostatic transmission

The February issue of *New Technology* contained an extensive feature on hydrostatic transmission. We wish to make it clear that in the diagram of a hydrostatic transmission system for a fork-lift truck (Figure 17) only the motor was of Carron manufacture, and not the whole system.

International Organisation of Legal Metrology (OIML)

The following documents have been circulated by OIML to member-countries for comment:

Titles: Material measures of length.
Verification of agent's standard pipettes.
Verification of agent's standard burettes.

References: Draft International Recommendations.

Copies may be obtained from Standards Weights and Measures Division, Department of Trade and Industry, Abell House, John Islip Street, London SW1P 4LN.

More information: Where possible, items in *New Technology* indicate the best sources of further information. Readers are advised also to seek information on matters relating to *New Technology* from the following DTI regional offices: Edinburgh 031-225 1822; Cardiff 62131; Newcastle upon Tyne 27575; Manchester, 061-832 9111; Leeds 38232; Nottingham 46121; Birmingham, 021-643 8221; Bristol 21071; London and South East, 01-684 9781; Eastern, 01-828 4355. In Northern Ireland, information is given by the Dept. of Industrial and Forensic Science, Belfast 64521.

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